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A RESURVEY OF THE WILLIAMSPORT DIVISION OF THE PHILADELPHIA AND READING RAILROAD.*

By GEORGE D. SNYDER, Assoc. M. Am. Soc. C. E.

ABSTRACT.

In 1890 the author was retained by the Philadelphia and Reading Railroad Company to make a survey of its line between Port Clinton and Newberry Junction, a distance of 125 miles. From Port Clinton to Sunbury the road has heavy grades and sharp curves, while from Sunbury to the end of the division the grades are light and the curves easy.

The survey was made to establish a working center line and to introduce transition curves where practicable. All physical features of the ground within a short distance on each side of the center line were located, and data obtained for establishing the right-of-way and property lines. A complete line of levels was to be run over the road, and working grades established for the track, but as the survey was not completed, this work was not finished. From the data obtained by the survey, maps and profiles of the line were prepared on which were

* The paper of which this is an abstract was accepted by the Committee on Publication for filing in the Library of the Society, where it may be examined. Further information concerning its contents may be obtained by application to the Secretary.

to be recorded all subsequent changes in tracks, alignment and right-of-way. This work, like the leveling, has never been finished.

In running the center line the tangents were established first. If the point of intersection was accessible, the intersection angle and the external secant were measured. With these data the degree of the curve was obtained which would fit between the two tangents and strike the apex of the curve. If an error of one to five minutes was allowable in the degree of curvature the latter was obtained on the slide rule by the formula $R =$ external secant $\div$ tan. $\frac{1}{2} I$ tan. $\frac{1}{2} I$, where R is the radius, and I the intersection angle. This formula is readily solved by the slide rule, which was employed largely in the computations made during the survey.

It was found inadvisable to run the tangents to an intersection where the ground was broken, uncleared or steep, as the measurements on the comparatively level roadbed were more accurate. In such cases the degree of the curve was obtained by holding a tape against the inside of the outer rail at points 62 ft. apart. The length in inches of the ordinate to the rail at the middle of the chord gave the curvature at that point in degrees. The mean of several measurements was assumed to be the degree of the curve. The location of the P. C. was then judged by the eye and a trial curve run, without putting in any stakes, to the end of the curve or until the trial line left the roadbed. In the latter case the distance D, from the trial line to the proposed center line at the last station was measured, and the distance, S, necessary to shift the P. C. was obtained by the formula $S = D \div \sin. A$, A being the total angle to the last station. By means of the slide rule, this shift can be ascertained readily, as well as the amount it will throw the line from the trial curve at each station. In this manner a new P. C. can be obtained and the curve run around to the next tangent.

When the degree of curvature found by means of the 62 ft. chord proved to be in error, the trial curve was generally inside or outside the track at its apex. Sometimes it was found that both the trial P. C. was incorrectly located and the degree of the trial curve was wrong. The data for changing the degree of the curve and shifting the P. C. were furnished by simple computations on the slide rule. Having run the trial curve for eight stations, say, the slide rule was set as explained previously for a shift of the P. C. to make the eighth

trial station strike the center line; the same setting also gave the distance this shift would move the fourth or middle trial station. The difference between this distance and the distance the fourth trial station had diverged from the center line gave the amount of change in the external secant necessary to make the curve fit the track. The degree of the new curve was then found by the slide rule. To find how far this new degree of curve would diverge from the trial curve and the track, the formula $O = \frac{7}{8} n^2 D$ was used, in which O is the offset from the tangent or from one curve to another, n is the number of 100-ft. stations, and D is the degree of the curve, or the difference in degree of two curves. This formula furnishes the data necessary to complete the location, and is particularly well adapted to the slide rule.

Transition curves were run by means of Froude's formula * $O = L^2 \div 24\ R$, in which O is the main offset from the circular curve to the tangent, L is the length of the transition curve, and R is the radius of the circular curve. By substituting $5730 \div D$ for R, the formula becomes $O = L^2\ D \div 137520$, where D is the degree of the curve. This curve is practically a cubic parabola having properties which enable all the computations involved in using it to be made on the slide rule. The transition curve bisects the main offset at the P. C., and is itself bisected by the offset line at this point. The offsets to the transition curve from the tangent or the circular curve are as the cubes of the distances, and the deflection angles to points on the transition curve are as the squares of the distances.

In the field, a simple curve which would fit the track was first found, and the offset was either assumed or calculated on the slide rule from an assumed length. If the tangents were offsetted and the same degree of curvature used as before, it would throw the whole curve toward the center a distance about equal to the offset. As this would generally throw the track off the road-bed, the usual practice was to sharpen the curve enough to make its apex strike the same place as before. To offset this the external secant of the new curve was reduced by an amount equal to O tan. $\frac{1}{2} I$, I being the intersection angle of the tangents. This distance was ascertained on the slide rule. From the point of the transition curve to the P. C., the offsets to the transition curve were set off from the tangent. The transit was then

* See Rankine's "Civil Engineering," p. 652.

placed over the P. C. and the remaining points of the transition curve located by offsets from main curve, the same offsets as before being used, but in an inverse order and an opposite direction.

The intermediate points on the transition curve can also be set by deflection angles. The total angle between the tangents at the beginning and end of the curve is equal to the total angle for the circular arc it replaces, and is obtained by multiplying the degree of the circular curve by half the length of the transition curve. One-third of this product is the deflection angle from the original tangent to the point where the transition and circular curves join. As the intermediate angles are as the squares of the distances, they are obtained readily on the slide rule. The offset method was generally found preferable, except where the transition curve is quite long. The same principles were applied in running one of these curves between two circular arcs.

The advantages of this method are as follows: The engineer is not limited to a certain number of curves with fixed lengths and offsets, as in methods where tables are used, but practically any length of transition curve can be used with any degree of curve. The calculations are all simple, and can be performed readily on the slide rule. The method of staking out and running the curve does not differ materially from ordinary curve work, and any transitman can learn the principles on which the method is based. It does not require complicated methods of plotting and keeping field notes. On original location, it adds nothing to the cost of the field work, as the transition curve need not be run, but merely provided for by making the necessary offsets at each P. C. and P. T., leaving the curve to be run in whenever necessary during construction, which will not be generally until track is to be laid. It will be found in numerous cases to facilitate location, because a long curve need not be rerun merely because it does not quite strike the terminal tangent, as any slight deviation will merely make the offset of the transition curve correspondingly greater or less.

Engineers who have been engaged on rerunning old locations know that the time spent by a party thus employed in actually marking the center line is but a small part of their working hours, and that much of their time is spent waiting for the man in charge to make the necessary calculations. To reduce to a minimum the delay caused

by these numerous computations, the author began the use of the slide rule. It was first employed in checking results, and, as confidence in it increased and a knowledge of its possibilities and limitations was obtained, some calculations were undertaken on it alone, and finally practically all of them, with the result that the party had little idle time.

The plotting was done very carefully. The maps were drawn on a scale of 1 in. to 50 ft., one-half mile being on each sheet. A longitudinal section of each bridge was shown, on which the general dimensions of the structure and its members were marked. The adjustment of the right of way was very difficult. The land was of slight value when the road was built, and little care was taken in drawing up the deeds. Many of them merely granted a right of way so many rods wide through a certain property in a certain township. As many of the deeds were drawn up in 1830, and there had been numerous changes in the ownership of adjoining properties since then, the title of nearly all the real estate along the line had to be traced back from forty to sixty years. All information relating to the right of way was tabulated on separate sheets, and a reference number on each separate purchase on the map showed on which sheet this information could be found. Index maps on a scale of 1 in. to 2 000 ft. were also prepared, as well as sketch maps of each train dispatcher's district. On the latter were indicated the main track, branches and all sidings, showing the number of cars each would hold.

The paper is accompanied by fifteen drawings, two photographs and an appendix giving slide rule settings applicable to field calculations on a railway survey.